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Preliminary analysis of built environment and cause specific visits to community health centres in Medan city, Indonesia

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Abstract

This study aims to analyse the relationship between urban built environmental features and population health in Medan city, Indonesia. We used the local community health centres as unit of analysis. We included nine urban environmental features as the independent factors for the number of visits for mental disorders, hypertension, diabetes type 2 and all cause mortality as our health outcomes. Poisson model revealed that increased transport infrastructures, open spaces and education institutes were associated with increased cause specific visits to health centres; while increased road intersections marginally decreased the visits. The prioritization of built environment for health in the scenario of Medan city might be different from the other cities.

Keywords: built environment, transport infrastructures, open spaces, mental disorders

Acknowledgement

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Introduction

The built environment where we live forms an integral part of our lives as it shapes most of our daily activities, such as transport, work, grocery shopping, entertainment and recreation. As we adjust our way of life according to our environment, such lifestyle often persists into our old age once we settle down at a place with our families. In addition, the built environment could have irreversible impacts on children growing up, which may determine their lifelong behaviours and health into their adulthood (Minh et al., 2017; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011). Therefore, the design and planning of the built environment in our living space is extremely important to our lifelong well being.

The contribution of built environment to health has been related in many previous studies. Increased spatial density, land use mix and recreational spaces have been associated with increased connectivity and opportunities for physical activity in urban areas (Bauman et al., 2012; Durand et al., 2011; Feng et al., 2010). Several studies have also found evidence that green spaces improve mental well being, and contribute to reduced mortality through physiological mechanisms (Bowler et al., 2010; Gascon et al., 2016; van den Berg et al., 2015). However, as causal relationship between built environment and health is difficult to establish due to the multiple personal factors and mediating confounders (McCormack and Shiell, 2011), most of the studies generally look at their statistical association. Results on certain built environmental attributes also varied across different population groups and methods adopted based on the available measurement metrics (Ferdinand et al., 2012; Van Cauwenberg et al., 2011). An example is a study by Saw et al. (2015) that indicated that green spaces did not contribute to the population well being in Singapore, which was highlighted as a tropical country compared to results from previous studies in temperate countries. While most of the evidence on the association between built environment and health were based on observational studies in developed countries such as Europe, United States, and Australia due to the availability of systematic data sets, evidence for developing countries in the local context need to be increased.

In this study, we attempt to explore the relationship between urban built environment and health in Medan city, Indonesia. Medan is the capital of North Sumatran province. As of 2016, its population reached a total of 2.2 million, making it the fourth largest city in Indonesia. Medan covers an area of 265.10 km^2, with an average density of 8,409 population per km^2 (BPS-Statistic of Medan Municipality, 2017a). It consists of 21 sub-districts (kecamatan) and 151 villages (kelurahan) (**Figure 1**). In the Green City Action Plan 2035 (GCAP) of Medan under the National Urban Development Policy and Strategy (NUDPS) (*Green City Action Plan 2035*, 2016), Medan is working towards becoming a clean, healthy and sustainable city. One of the short term prioritization in the strategy is to improve public transportation, while green spaces and urban forests are included in the long term strategy. This study aims to explore the health implications from the local built environment in Medan city. The results presented in this study is an analysis of aggregated data collected from local agencies in Medan city to provide a preliminary view of the relationship between the environmental features and health in the city.

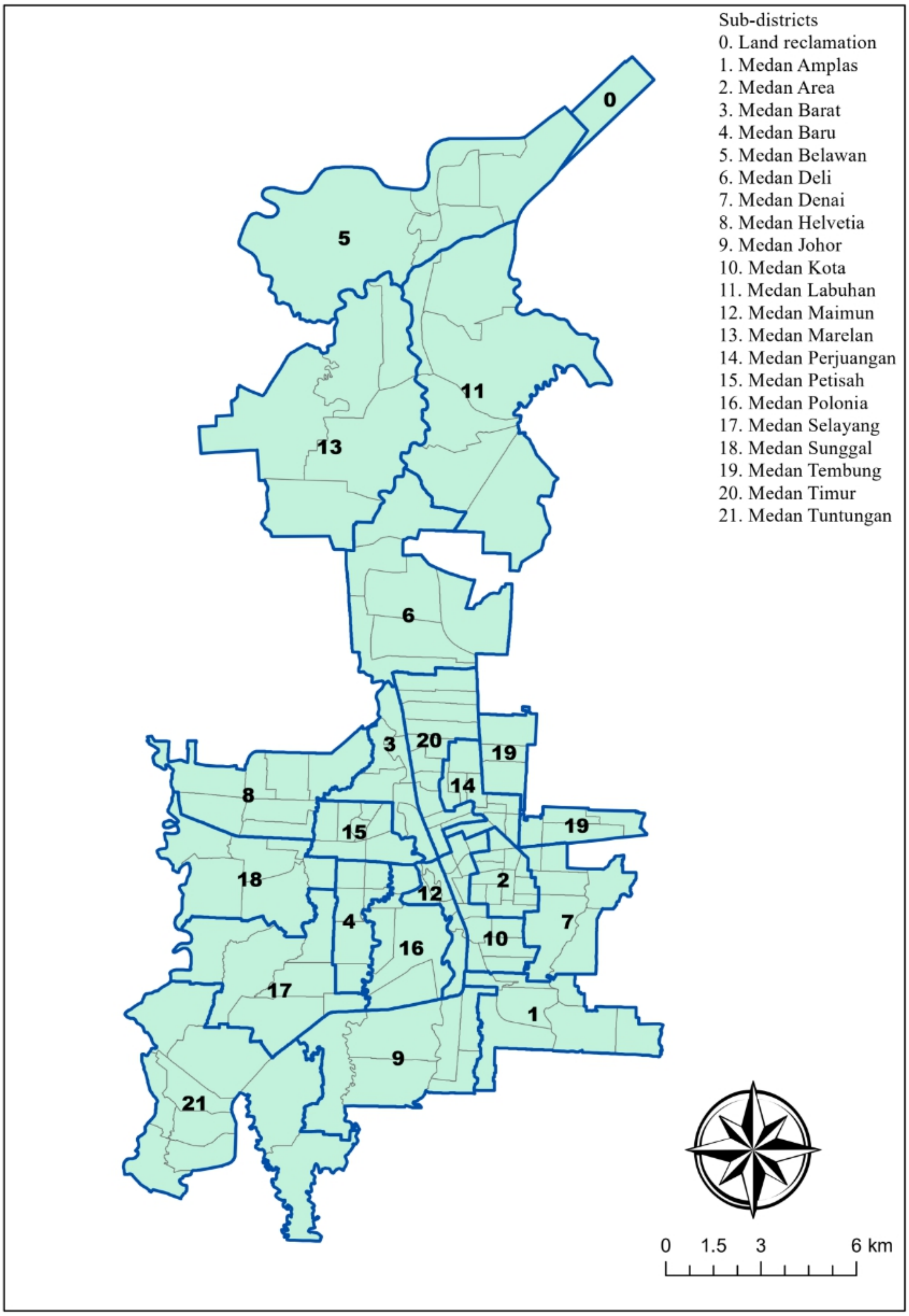


Figure 1 Administrative map of sub-districts and villages in Medan city

Methods

Unit of analysis

In this study, we used local community health centres (Pusat Kesehatan Masyarakat or Puskesmas) as the unit of analysis. There are 39 health centres distributed in Medan city. Each health centre covers one or more villages depending on the size of village population and roads of access to the health centres. Therefore, each sub-districts in Medan city may have a minimum of one to four health centres, while each health centre could cover up to 11 villages for community healthcare. **Table S1** shows the villages covered under each health centre. To get the population number and density based on the villages under each health centre, we manually extracted the information for all villages in year 2016 from the annual reports of each sub-districts in 2017 (BPS-Statistic of Medan Municipality, 2017b). Then, we aggregated the population sizes, and averaged the population densities of these villages to get the population information for each health centres. The population density of the area for each health centre was included as one of the independent factors in our analyses.

Health data

We obtained the number of cause specific visits to the 39 local community health centres in 2016 from the Health Service Department in Medan city (Dinas Kesehatan Kota Medan). We got the number of visits for mental disorders, hypertension, diabetes type 2, coronary heart disease, and obesity as our diseases of interests. However, due to too many missing values for coronary heart disease and obesity, we did not include them in our analyses. We also excluded one health centre (Simpang Limun) for hypertension and diabetes for missing data. For all cause mortality, we extracted the data manually from the annual reports of each sub-districts in 2017 (BPS-Statistic of Medan Municipality, 2017b). There were 9 sub-districts which did not have the number of mortality in the reports, and were treated as missing values in the analyses.

Environmental features

We obtained the information on existing land use and physical environment of Medan city from the Planning and Development Agency of Medan city (Bappeda Kota Medan). We included nine parameters including four transport infrastructure or services, and five land use metrics as our focus of analyses on environmental features. All the parameter measurements were divided according to the boundaries of villages covered under each health centre.

The transport parameters included mini bus service routes, rail tracks currently in use for people, non-arterial roads and road intersections for connectivity. Based on the data given, there are eight road types in Medan city. We excluded the arterial roads, given that these roads would not be conducive for any potential engagement in active transportation. The pedestrian walkway was not included in the land use map of Medan city as there is no official designation of pedestrian walkways in Medan city planning, although they may exist irregularly in some parts of the roads in the city.

For land use, we included the net residential density, land use mix, densities of open spaces, places of worship, and educational institutes in the city. Net residential density was defined as the number of population per total residential area in Medan city (Frank et al., 2005). We calculated the entropy index as a measure of land use mix based on the formula below:

$$\text{Entropy index} = - \sum_{i=1}^{k} \frac{P_i \times \ln(P_i)}{\ln(k)}$$

where k is the number of land use type, and P_i is the proportion of the land use type in the village or villages. We included seven types of land uses in the calculation: low residential density area, average residential density area, high residential density area, commercial area, trading area, service area, and open spaces. The residential density was categorized based on the building width, with smaller building width depicting higher density. The commercial area consisted mainly of services such as banking, transport hubs, learning institutions, communications, health care, entertainment and private company offices. The trading area consisted of areas with permanent or temporary merchants, small stores, supermarkets, department stores, traditional markets, restaurants, petrol stations, and malls. The office area consisted mainly of government offices, library, institutions, schools, religious place of worship in Medan city. Open spaces were defined as green spaces, blue spaces, and open tourist attraction areas.

In the data given, there were eight categories of open spaces in Medan city. They were the urban forests, tourist spots, spaces for sports, village parks, city parks, cemetery, open land spaces and blue spaces. We re-categorized these spaces into three types. We combined the urban forest, village parks, urban parks into green spaces category; the tourist spots, spaces for sports, and open land spaces into open spaces category; and blue spaces in one category. We excluded the cemetery as we did not consider it as a place for activities. To combine the three categories into one composite measurement, we calculated the sum of their Z scores.

Considering the possibly important role of religion in the local community, especially on the mental health, we included the density of the places of worship in the model. We also included density of educational institutes as a potential independent factor of health.

Data analysis

We used quasi-Poisson regression to analyse the count data of cause specific visits to local community health centres in IBM SPSS version 22. Metrics of transport infrastructures and land uses were produced using ArcMap 10.4.1. The dependent variables were the health data while the independent variables were the physical features as described above. As schizophrenia, and mixed anxiety and depressive disorder topped the visits for mental disorders, we also ran the analyses on them separately (**Figure S1**). Population size in year

2016 was inserted as the offset variable. In order to test the hypothesis on the gender disparity in the effect of built environment observed in previous studies (Lake and Townshend, 2013; Bel and Hanes, 2013), we ran the analyses on male and female for the visits for mental disorders, where it was the only variable with available gender segregation.

Results

Descriptive statistics

The population size covered under a health centre ranged from 11,029 to 167,984 people in 2016 (**Table S1**). Terjun health centre covered the largest population size followed by Medan Deli and Helvetia health centre. The number of population corresponded with the number of households in the villages, with an average of 4.32 members in each household.

The cause specific visits for mental disorders were categorized into 16 types as shown in **Figure S1**. A total of 7,846 visits were recorded for mental disorders in Medan city. Visits for schizophrenia and other primary psychotic disorder constituted more than half of the total mental disorders (54%), followed by mixed anxiety and depressive disorder (MADD) (12%). Helvetia health centre had the highest number of visits for mental disorders (9.4%) in 2016, followed by Padang Bulan (6.8%) and Sentosa Baru (6.3%). Padang Bulan had the highest number of visits for both schizophrenia and other primary psychotic disorder (7.8%), and MADD (20.6%) among all the local community health centres.

In 2016, there were 59,841 and 34,312 visits for hypertension and diabetes type 2, respectively in Medan city. Helvetia (12.1%; 13.4%), Martubung (6.0%; 9.6%) and Medan Deli (9.4%; 6.7%) health centres topped the number of visits for the both diseases. **Table 1** shows the variations in the number of cause specific visits to the health centres in Medan city in 2016. For all cause mortality among the villages with available data, villages under Mandala health centre area had the highest number of mortality.

Table 1 Descriptive statistics of cause specific visits to local community health centres and all cause mortality in Medan city for 2016

Cause of visits	Mean	s.d.	Minimum	Median	Maximum	IQR
Mental disorders (n=39)	201	157	22	138	737	172
Schizophrenia and other primary disorders	109	73	0	93	333	95
Mixed depressive and anxiety disorder	24	42	0	4	191	5
Hypertension (n=38)	1,575	1,403	122	1,204	7,212	721
Diabetes type 2 (n=38)	903	895	63	654	4,587	841
All cause mortality (n=30)	258	207	24	174	781	289

There is a considerably high variability in the distribution of the population density, transport infrastructures and land uses between the areas (**Table 2**). The area with the highest population density is Sei Agui, while Teladan has the highest net residential density (**Table S2**). The public transport infrastructure in Medan city is still under development. Teladan (6.8%) and Bestari (6.1%) have the highest concentration of minibus routes, while rail services are only available across several villages, with most concentrating in areas in Pulo Brayan (14.1%), and Glugur Kota (13.9%). Kota Matsum has the highest density of non-arterial roads while Medan Labuhan has the lowest density. For land use mix, Padang Bulan and Polonia score the highest entropy index (LUM7= 0.91). The amount of open spaces (green, open and blue) varies widely across the areas, with the Z scores ranging from -1.92 (Pasar Merah) to 6.45 (Belawan). Polonia has the highest density for green spaces (12%), while Medan Labuhan contains the most open spaces (26%) among all areas. Belawan is covered by the most rivers for blue spaces (27%) as it is situated near to the coastal region.

Correlation matrix in **Table 3** shows that road density is highly correlated with intersection density. Besides, it seems that road and intersection density have highly negative correlations with the density of open spaces.

Table 2 Descriptive statistics of environmental features (n=39)

Features	Unit	Mean	s.d.	Minimum	Median	Maximum	IQR
Population density	person/km^2	13,148.64	8,832.47	1,656.50	11,582.50	47,512.00	9,768. 00
Minibus route	km/area width (km^2)	2.24	1.36	0.07	2.27	5.93	2.03
Rail track in use	km/area width (km^2)	0.35	0.50	0.00	0.07	1.93	0.57
Roads density	km/area width (km^2)	17.98	6.40	3.26	18.78	29.05	29.04
Road intersection density	number/area width (km^2)	290.21	145.35	36.05	264.90	627.25	417.86
Entropy index (LUM7)	Range 0 to 1	0.62	0.17	0.30	0.65	0.91	0.29
Green, open and blue spaces	Z-score of km^2/area width (km^2)	0.00	2.21	-1.92	-0.73	6.45	1.41
Net residential density	person/ residential area width (km^2)	27,089.66	14,868.07	3,485.94	25,280.16	76,078.42	21,818.52
Worship place density	Number/ 10,000 population	3.69	2.34	0.41	3.61	10.46	2.75
Education institute density	Number/ 10,000 population	4.98	4.39	0.10	3.84	22.72	5.19

Table 4 shows the Poisson log-linear regression model between the built environment features and the number of cause specific visits to health centres. The model

shows that the total visits for mental disorders significantly increased with increased density of rail, roads, open spaces, and educational institutions in the area. Separate analysis for schizophrenia did not find any significant associations. However, mixed anxiety and depressive disorder (MADD) produced similar trends of association as the total visits for mental disorders. All the significant features increased the number of visits for MADD except for intersection density where its increase reduced the number of visits by a marginal 1%. Rail density seemed to have the largest effects on these visits for mental disorders. Comparing the number of visits for total mental disorders and MADD between male and female, the type of environmental features that were significantly associated were consistent with the main results (**Table S3**). Though, the females seemed to have higher effect sizes for rail density (RR = 2.54 (female); 1.93 (male)) and road density (RR = 1.26 (female); 1.16 (male)); while the males had the higher effects from the density of open spaces (RR =1.26 (male); 1.24 (female)) and educational institutions (RR =1.10 (male); 1.09 (female)). The effects of road intersection on both males and females were about the same.

The increase in visits for hypertension was significantly associated with increased rail density, while increased visits for diabetes type 2 was associated with both increased rail and road density. Road intersection was associated with a marginal reduction in the visits for diabetes type 2 by 1%. On the other hand, all cause mortality did not show any statistically significant associations with the environmental features. **Figure 2** shows the relative risks for the cause specific visits and all cause mortality for the significant environmental features. Although not significant, the effects of the environmental features on the relative risk for all cause mortality were observed to have opposite directions to that of the cause specific visits. There were reductions in all cause mortality with regards to increased environmental features, except for a slight increase from increased road intersection density.

Table 3 Pearson's correlation between urban features

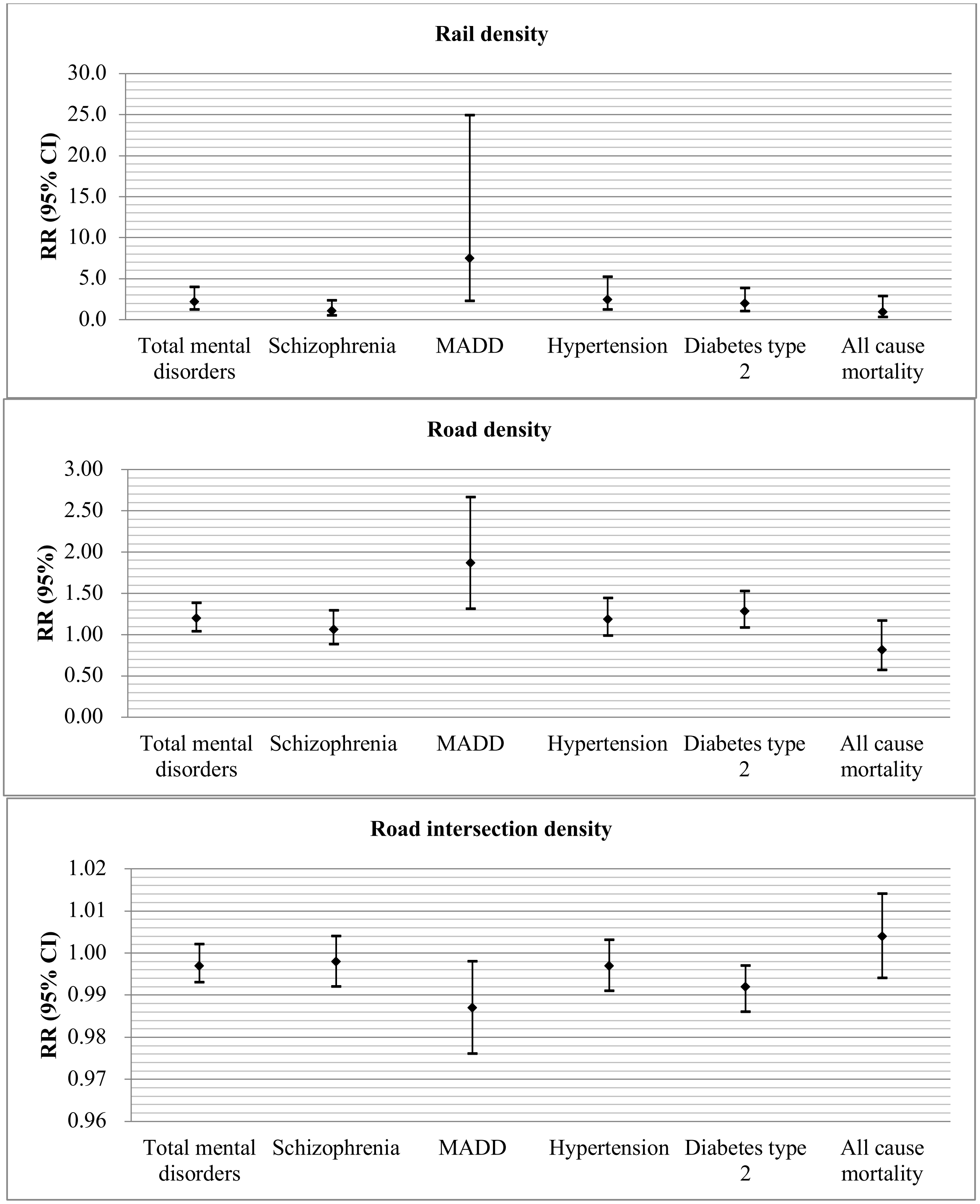
Features	Population density 2016	Minibus route density	Rail density	Road density	Intersection density	Entropy index (LUM7)	Net residential density	Density of open spaces (Z-score)	Density of place of worship	Density of educational institutes
Population density	1	0.339*	0.174	0.627**	0.597**	-0.542**	0.471**	-0.494**	0.152	0.049
Minibus route density	0.339*	1	0.449**	0.637**	0.561**	0.073	0.683**	-0.557**	0.129	0.428**
Rail density	0.174	0.449**	1	0.068	0.053	-0.05	0.483**	-0.191	-0.016	0.096
Road density	0.627**	0.637**	0.068	1	0.943**	-0.386*	0.512**	-0.819**	0.243	0.258
Intersection density	0.597**	0.561**	0.053	0.943**	1	-0.382*	0.458**	-0.700**	0.192	0.225
Entropy index (LUM7)	-0.542**	0.073	-0.05	-0.386*	-0.382*	1	-0.235	0.275	-0.213	-0.089
Net residential density	0.471**	0.683**	0.483**	0.512**	0.458**	-0.235	1	-0.396*	-0.052	0.421**
Density of open spaces (Z-score)	-0.494**	-0.557**	-0.191	-0.819**	-0.700**	0.275	-0.396*	1	-0.27	-0.259
Density of place of worship	0.152	0.129	-0.016	0.243	0.192	-0.213	-0.052	-0.27	1	0.383*
Density of educational institutes	0.049	0.428**	0.096	0.258	0.225	-0.089	0.421**	-0.259	0.383*	1

**p<0.01 *p<0.05

Table 4 Relative risk of all cause mortality and cause specific visits to health centres in relation to environmental features

Features	RR (95% CI)					
	Mental disorders (n=39)	Schizophrenia (n=39)	Mixed anxiety and depressive disorder (n=39)	Hypertension (n=38)	Diabetes type 2 (n=38)	All cause mortality (n=30)
Population density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Minibus route density	0.91 (0.67, 1.23)	1.33 (0.93, 1.89)	0.84 (0.38, 1.84)	0.76 (0.51, 1.13)	1.00 (0.69, 1.44)	1.88 (0.98, 3.59)
Rail density	2.16 (1.19, 3.92)*	1.05 (0.48, 2.31)	7.49 (2.26, 24.91)*	2.44 (1.15, 5.16)*	1.96 (1.02, 3.77)*	0.89 (0.28, 2.82)
Road density	1.20 (1.04, 1.39)*	1.07 (0.88, 1.29)	1.87 (1.31, 2.66)*	1.19 (0.99, 1.44)	1.29 (1.08, 1.53)*	0.82 (0.57, 1.17)
Intersection density	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	0.99 (0.98, 1.00)*	1.00 (0.99, 1.00)	0.99 (0.99, 1.00)*	1.00 (0.99, 1.01)
Entropy index (LUM7)	4.54 (0.89, 23.28)	2.11 (0.26, 16.88)	25.61 (0.33, 2019.47)	5.82 (0.76, 44.69)	1.20 (0.19, 7.40)	0.39 (0.01, 13.19)
Net residential density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)*	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Density of open spaces (Z-score)	1.27 (1.07, 1.50)*	1.23 (0.98, 1.54)	1.19 (0.71, 2.00)	1.05 (0.85, 1.30)	1.09 (0.89, 1.32)	0.87 (0.57, 1.32)
Density of place of worship	0.95 (0.84, 1.06)	1.00 (0.86, 1.15)	0.74 (0.54, 1.02)	1.07 (0.95, 1.22)	0.97 (0.85, 1.10)	1.22 (0.99, 1.50)
Density of educational institutes	1.10 (1.05, 1.16)*	1.03 (0.96, 1.10)	1.20 (1.08, 1.34)*	1.05 (0.98, 1.13)	1.05 (0.99, 1.12)	0.90 (0.77, 1.05)

*p<0.05


Rail density
RR (95% CI)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Total mental disorders
Schizophrenia
MADD
Hypertension
Diabetes type 2
All cause mortality
Road density
RR (95%)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Total mental disorders
Schizophrenia
MADD
Hypertension
Diabetes type 2
All cause mortality
Road intersection density
RR (95% CI)
1.02
1.01
1.00
0.99
0.98
0.97
0.96
Total mental disorders
Schizophrenia
MADD
Hypertension
Diabetes type 2
All cause mortality

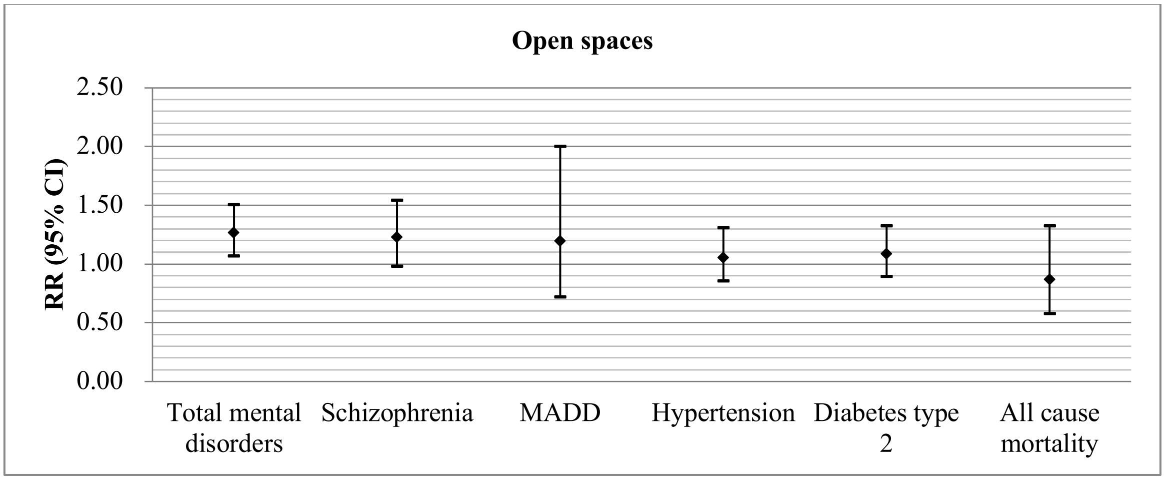


Figure 2 Relative risks of cause specific visits and all cause mortality in association with built environment.

Sensitivity analysis

The initial model without including the density of place of worship and educational institutes returned only open spaces as the significant factor on mental disorders (RR = 1.24 (1.02, 1.52)), while the significant features for hypertension, diabetes and all cause mortality remained the same. Adding the density of places of worship returned the same results. However, adding the density of education institutes gave more number of significant features that affected the number of visits for mental disorders, as shown in the main results.

Due to the high correlation between road intersection and road density, we tested the model by excluding either one of them from the model. When we included road density in the predictors, the result remain approximately the same as the main results for mental disorders, hypertension and all cause mortality, while no significance was found for diabetes. When we included the road intersection in the predictors, only education density appeared to be the significant feature for the visits for mental disorders (RR= 1.09 (1.03, 1.15)), while no significance were found for all the other diseases.

Discussion

Given the majority of the past studies on the relationship between built environment and health were done in developed countries, we attempt to find out if the pattern of the relationship is similar in the context of a developing country (Indonesia) in the Southeast Asian region. Using the existing data from the local community health centres in the city of Medan, we analyzed the number of cause specific visits to the health centres, and all cause mortality in relation to the environmental infrastructures. The Poisson regressions suggested that while increased transport infrastructures (rails, roads), open spaces, and educational institutes were associated with increased visits to health centres for the specific causes, the number of all cause mortality seemed to follow the opposite direction in the relationship. In addition, it was observed that increased road intersections marginally decreased the number of visits but increased the all cause mortality.

Increased urban density and public transport infrastructures have often been related to positive health impacts, mainly from the expectations that people walk more in a compact environment which contributes to active living (Melis et al., 2015; Sallis et al., 2016). However, such effects did not show in this study, which revealed negative effects of both increase in rail and road densities on the number of visits to health clinics in the area. This is unsurprising as the public transport network in Medan city is still under a very early development stage (Basuki Joewono et al., 2007), with the most recent one being the rail link connecting the airport to the city. Similar to other developing countries, the transport infrastructures in Medan are mainly automobile oriented with limited spaces to walk. The local people also rely heavily on local traditional transportations such as ‘becak’ (cycle rickshaws) and ‘gojek’ (motorbike taxis) for short distances, or share the walking spaces on the curb of the roads which function equally as parkings and waiting areas for cars and motorcycles. As transport facilities often denote level of urbanization, it is likely that the rails and roads contributed more negative health impacts from the amount of traffic noise and air pollution than physical activity in the area (Buchari and Matondang, 2017), which were reflected in the increased visits to health centres. Transport noise and air pollution have been shown to increase the incidence of hypertension and diabetes (Clark et al., 2017; Fuks et al., 2011), and cause annoyances and sleep disturbances which are detrimental to mental health (Sygna et al., 2014). In addition, several studies have shown that increased urbanization and higher density of transport infrastructures were actually associated with increased prevalence of diabetes (Attard et al., 2012; DenBraver et al., 2018).

One exception to the transport metrics that showed significant but marginally positive effect was road intersection density on the visits for MADD and diabetes type 2. This result is unforeseen, judging from the earlier results from roads and rails. The potential role of road intersections offering more walkability or other potential factors compared to road and rail infrastructures need to be further studied. For open spaces, our study did not show any significant association with the number of visits in general. In contrary, there was a positive association with mental disorders, which was controversial to the protective effects suggested by previous studies (Gascon et al., 2015). One possible explanation to it might be the quality and aesthetic conditions of these spaces, which we did not account in this study. Previous studies have found that the management of green spaces are equally important to encourage their usage in contribution to health (Nasution and Zahrah, 2014; Galea et al., 2005; van Dillen et al., 2012). All cause mortality did not show any significant relationship with any of the urban infrastructures. A previous study suggested that higher junction density was associated with 12% more premature mortality risk (Fecht et al., 2016), but such association was not found in this study. However, based on **Figure 2**, all the significant environmental infrastructures decreased the relative risks of all cause mortality except for the density of road intersection.

It is noted that the number of visits to local community health centres may not be the same as the number of incidence of diseases. Although visits to health centres are often related to the health conditions of population, increased visits to health centres could be mediated by other factors, and may not necessary indicate negative population health outcomes. Instead, it could also imply that the higher infrastructure density allows people to have good access to health care, thereby reducing the mortality rate in the area. As with all studies using secondary data, this study was limited by the availability and quality of the data. There might be other covariates such as regional income that could affect the relationship, but was not included in this analysis. The density of educational institutes could in part be a proxy to the local economy, and thus acted as a significant factor in the visits for mental disorders. In addition, the Medan local health department is at the initial stage of compiling disease specific health statistics, and developing the health information system, therefore, flaws such as incomplete submission records from health centres, and missing data were common. Besides, due to the aggregated nature of the data set, the results of this study were based on small sample size and large area coverage in each sample (health center). These limitations should be addressed in the future studies of Medan city.

Conclusion

This study offers a preliminary overview of the built environment and health in Medan city. It shows that the priorities in urban built environment and health that need to be tackled in the scenario of Medan city might be different from the other cities in previous studies. Currently, it seems that the negative effects of environmental infrastructure density including rail transport outweighed their benefits for health. This is probably due to the present insufficient infrastructure development to support a health conducive environment locally. More specific health implications from the environmental features might only be observed with smaller area studies and more detailed data with the aim of establishing causal relationship. Factors that could mediate the relationship between built environment and health such as measurements of air pollutant, noise and physical activity in Medan city may be incorporated in future studies.

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Supplementary materials

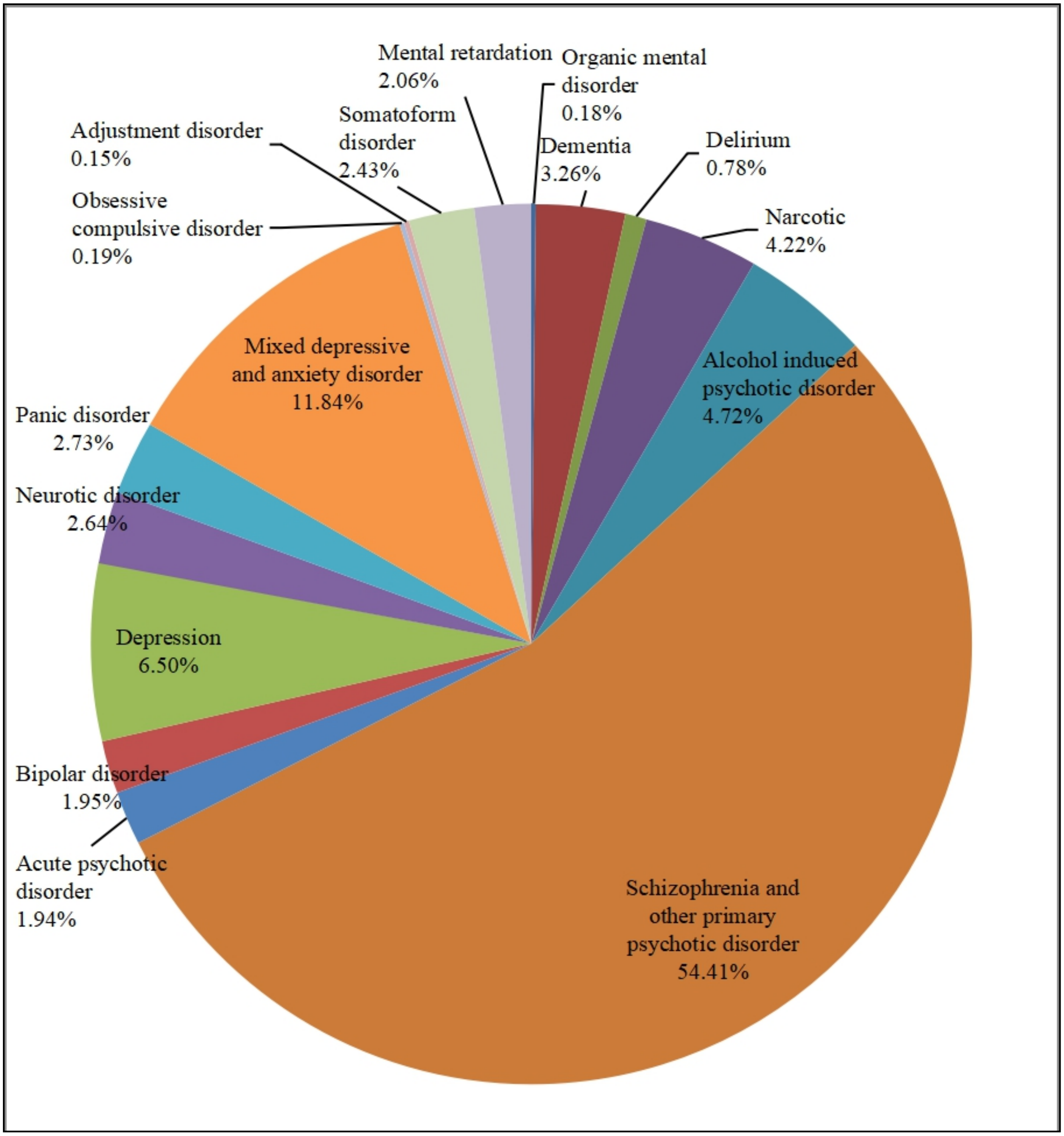

Figure S1 Percentage distribution of type of mental disorder visits to Medan health centres in 2016

Table S1 The sub-districts and villages under the coverage of local community health centres

Sub-districts (Kecamatan)	Villages (Kelurahan)	Local community health centres (Puskesmas)
Medan Amplas	Amplas	Amplas
	Bangun Mulia	
	Harjosari 1	
	Harjosari 2	
	Sitirejo 2	
	Sitirejo 3	
	Timbang Deli	
Medan Area	Kota Matsum 1	Kota Matsum
	Kota Matsum 2	
	Kota Matsum 4	
	Sei Rengas Permata	
	Pandau Hulu 2	Medan Area Selatan
	Sei Rengas 2	
	Sukaramai 1	
	Sukaramai 2	
	Pasar Merah Timur	Sukaramai
	Tegal Sari 1	
	Tegal Sari 2	
	Tegal Sari 3	
Medan Barat	Kesawan	Glugur Kota
	Silalas	
	Glugur Kota	Pulo Brayan
	Pulo Brayan Kota	
	Karang Berombak	Sei Agul
	Sei Agul	
Medan Baru	Babura	Padang Bulan
	Darat	
	Merdeka	
	Padang Bulan	
	Petisah Hulu	
	Titi Rantai	
Medan Belawan	Bagan Deli	Belawan
	Belawan Bahagia	
	Belawan Bahari	
	Belawan I	
	Belawan II	
	Belawan Sicanang	
	Reklamasi Pantai	
Medan Deli	Kota Bangun	Medan Deli

	Mabar	
	Mabar Hilir	
	Tanjung Mulia	
	Tanjung Mulia Hilir	
	Titi Papan	Titi Papan
Medan Denai	Tegal Sari Mandala 2	Bromo
	Binjai	Desa Binjai
	Denai	Medan Denai
	Medan Tenggara	
	Tegal Sari Mandala 1	Tegal Sari
	Tegal Sari Mandala 3	
Medan Helvetia	Cinta Damai	Helvetia
	Dwikora	
	Helvetia	
	Helvetia Tengah	
	Helvetia Timur	
	Sei Kambing C II	
	Sei Sikambing C II	
	Tanjung Gusta	
Medan Johor	Kedai Durian	Kedai Durian
	Suka Maju	
	Titi Kuning	
	Gedung Johor	Medan Johor
	Kwala Bekala	
	Pangkalan Masyhur	
Medan Kota	Kota Matsum 3	Pasar Merah
	Pasar Merah Barat	
	Sei Rengas 1	
	Teladan Timur	
	Sitirejo 1	Simpang Limun
	Sudi Rejo 1	
	Sudi Rejo 2	
	Mesjid	Teladan
	Pandau Hulu 1	
	Pasar Baru	
	Pusat Pasar	
	Teladan Barat	
Medan Labuhan	Besar	Martubung
	Tangkahan	
	Martubung	Medan Labuhan
	Sei Mati I	
	Nelayan Indah	Pekan Labuhan
	Pekan Labuhan	
Medan Maimun	Aur	Kampung Baru
	Hamdan	
	Jati	

	Kampung Baru Sei Mati II Suka Raja	
Medan Marelan	Labuhan Deli Paya Pasir Rengas Pulau Tanah Enam Ratus Terjun	Terjun
Medan Perjuangan	Pahlawan Pandau Hilir Sei Kera Hilir 2 Sei Kera Hilir I Sei Kera Hulu Sidorame Barat 1 Sidorame Barat 2 Sidorame Timur Tegal Rejo	Sentosa Baru
Medan Petisah	Petisah Tengah Sei Putih Timur I Sekip	Bestari
	Sei Putih Barat Sei Sikambing D	Darussalam
	Sei Putih Tengah Sei Putih Timur II	Rantang
Medan Polonia	Anggrung Madras Hulu Polonia Sari Rejo Suka Damai	Polonia
Medan Selayang	Asam Kumbang Beringin Padang Bulan Selayang 1 Padang Bulan Selayang 2 Sempakata Tanjung Sari	Padang Bulan Selayang
Medan Sunggal	Lalang Sei Sikambing	Lalang
	Baburakwala Batuan Simpang Tanjung Sunggal Tanjung Rejo	Sunggal
Medan Tembung	Bandar Selamat Bantan Bantan Timur Tembung	Mandala
	Indra Kasih	Sering

	Sidorejo	
	Sidorejo Hilir	
Medan Timur	Durian	Glugur Darat
	Gaharu	
	Gang Buntu	
	Glugur Darat 1	
	Glugur Darat 2	
	Perintis	
	Pulo Brayan Bengkel Baru	
	Pulo Brayan Bengkel Lama	
	Pulo Brayan Darat 1	
	Pulo Brayan Darat 2	
	Sidodadi	
Medan Tuntungan	Mangga	Simalingkar
	Simalingkar B	
	Simpang Selayang	
	Baru Ladang Bambu	Tuntungan
	Kemenangan Tani	
	Lau Cih	
	Namo Gajah	
	Sidomulyo	
	Tanjung Selamat	

Table S2 Characteristics of environmental features according to areas of health centres

Health centre	Population 2016	Population density 2016	Minibus route density	Rail density	Road density	Road intersection density	Entropy index (LUM7)	Net residential density	Density of open spaces (Z score)	Density of places of worship	Density of educational institutions
Amplas	126,340	13,658.71	1.18	0.00	18.39	319.30	0.42	18,001.96	-0.90	4.20	4.35
Belawan	98,167	10,544.71	0.36	0.16	4.21	60.36	0.53	24,769.12	6.45	0.41	0.10
Bestari	23,761	13,573.33	5.36	0.44	22.42	361.87	0.71	46,832.76	-0.59	0.42	1.68
Bromo	20,637	23,667.00	2.93	0.92	19.31	221.75	0.38	45,739.95	-1.57	9.21	7.75
Darussalam	21,405	11,291.50	3.47	0.34	22.94	403.18	0.61	20,536.45	-1.21	9.34	6.07
Desa Binjai	45,778	11,032.00	1.14	0.00	24.56	448.86	0.39	21,839.27	0.08	3.71	3.71
Glugur Darat	111,547	14,137.09	2.62	0.60	18.76	309.13	0.71	25,280.16	-1.33	2.33	2.15
Glugur Kota	11,029	2,755.50	3.90	1.89	15.81	259.45	0.86	30,261.51	-0.14	3.63	2.72
Helvetia	151,580	13,003.43	2.27	0.35	20.07	303.37	0.67	19,465.35	-0.96	2.57	3.96
Kampung Baru	40,690	14,970.67	2.86	0.00	18.78	264.69	0.81	32,907.61	-0.48	0.74	2.46
Kedai Durian	40,185	8,885.00	1.15	0.00	17.05	209.65	0.30	14,813.37	-1.15	4.73	8.46
Kota Matsum	29,656	25,789.25	1.89	0.00	29.05	583.44	0.43	44,226.15	-1.81	5.73	11.13
Lalang	42,243	11,582.50	2.89	0.03	19.69	353.50	0.82	18,133.60	-0.52	4.97	2.84
Mandala	82,118	18,186.25	1.96	1.01	17.90	188.72	0.34	35,005.89	-1.85	4.99	3.90
Martubung	57,534	4,793.00	0.07	0.07	10.72	165.28	0.53	11,131.88	-0.03	2.09	1.91
Medan Area Selatan	28,592	19,257.50	3.50	1.03	24.98	461.47	0.54	53,750.16	-1.11	4.90	7.34
Medan Deli	151,892	8,129.80	1.08	0.29	13.84	180.37	0.82	33,697.89	-0.95	1.19	1.38
Medan Denai	37,830	11,885.00	2.02	0.00	22.74	378.22	0.42	19,177.32	-0.15	3.70	5.02
Medan Johor	93,461	7,519.33	1.61	0.00	16.86	239.87	0.69	11,834.67	-0.41	3.64	4.07
Medan Labuhan	32,229	1,656.50	0.40	0.27	3.26	36.05	0.65	10,006.91	5.94	3.72	5.59
Padang Bulan	40,560	7,723.17	3.40	0.00	19.34	264.90	0.91	17,906.68	-0.59	4.19	14.05
Padang Bulan Selayang	107,831	5,757.00	2.30	0.00	15.15	181.19	0.78	12,133.12	1.05	3.34	3.34
Pasar Merah	23,431	14,352.00	3.53	0.36	22.74	485.84	0.58	37,089.08	-1.92	3.41	11.52
Pekan Labuhan	28,788	3,708.50	0.60	0.43	5.30	54.74	0.65	28,017.29	4.68	1.74	4.17
Polonia	56,513	4,558.40	0.71	0.00	10.60	106.90	0.91	27,844.96	3.49	2.48	0.71
Pulo Brayan	20,115	14,920.00	3.11	1.93	17.02	256.48	0.59	37,155.27	-0.72	0.99	0.99

Rantang	18,224	22,134.00	3.51	0.66	28.42	627.25	0.47	33,380.84	-1.57	4.94	3.84
Sei Agul	41,573	47,512.00	2.56	0.85	20.77	364.87	0.49	27,257.59	-0.73	3.61	2.65
Sentosa Baru	95,935	19,793.22	2.36	0.01	25.74	401.93	0.49	38,918.67	-1.49	2.19	3.34
Sering	64,242	17,022.67	2.00	0.00	17.87	222.16	0.69	27,314.09	-1.67	2.96	1.71
Simalingkar	57,709	7,254.67	0.61	0.00	11.36	144.16	0.75	7,203.17	3.70	1.21	1.04
Simpang Limun	29,024	14,196.00	1.86	0.00	21.51	452.91	0.68	21,062.94	-1.64	0.69	0.34
Sukaramai	37,504	27,644.00	3.83	0.00	25.12	437.53	0.36	41,509.98	-1.44	5.60	8.53
Sunggal	73,594	6,788.25	3.04	0.00	19.38	303.79	0.81	15,270.56	-0.63	6.25	3.40
Tegal Sari	42,143	26,061.00	2.64	0.30	26.34	498.54	0.37	44,258.05	-1.52	5.22	5.22
Teladan	22,006	10,799.20	5.93	1.12	20.87	327.64	0.73	76,078.42	-0.95	2.73	22.72
Terjun	167,984	4,685.40	0.68	0.00	9.73	123.33	0.68	8,964.95	4.21	2.32	2.86
Titi Papan	32,870	8,218.00	0.95	0.57	13.46	212.31	0.60	14,233.19	-0.99	3.35	8.82
Tuntungan	27,716	3,351.33	0.93	0.00	9.12	103.36	0.86	3,485.94	1.44	10.46	8.66

Table S3 Relative risks of mental disorders and MADD between genders in relation to environmental features

Features	RR (95% CI)			
	Mental disorders (n=39)		Mixed anxiety and depressive disorder (n=39)	
	Male	Female	Male	Female
Population density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Minibus route density	0.89 (0.67, 1.18)	1.04 (0.72, 1.49)	0.73 (0.34, 1.58)	1.27 (0.54, 2.99)
Rail density	1.93 (1.06, 3.52)*	2.54 (1.32, 4.91)*	4.44 (1.07, 18.34)*	11.56 (3.72, 35.89)*
Road density	1.16 (1.01, 1.34)*	1.26 (1.06, 1.51)*	1.73 (1.20, 2.51)*	2.08 (1.43, 3.03)*
Intersection density	1.00 (0.99, 1.00)	1.00 (1.00, 1.00)	0.99 (0.98, 1.00)*	0.98 (0.97, 1.00)*
Entropy index (LUM7)	4.58 (0.97, 21.64)	3.18 (0.43, 23.42)	12.94 (0.19, 862.53)	16.58 (0.12, 2323.432)
Net residential density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)*
Density of open spaces (Z-score)	1.26 (1.07, 1.48)*	1.24 (1.00, 1.54)*	1.30 (0.82, 2.07)	0.77 (0.33, 1.76)
Density of place of worship	0.94 (0.84, 1.05)	0.95 (0.83, 1.09)	0.77 (0.55, 1.08)	0.70 (0.51, 0.95)
Density of educational institutes	1.10 (1.05, 1.16)*	1.09 (1.03, 1.15)*	1.20 (1.06, 1.35)*	1.20 (1.08, 1.33)*